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Large anisotropic single crystal epitaxial graphene flakes isolated from SiC wafers

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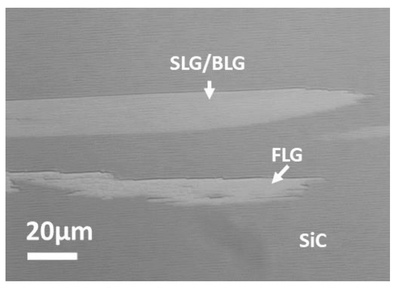
MARIE CURIE ACTIONS
DOC-FAM

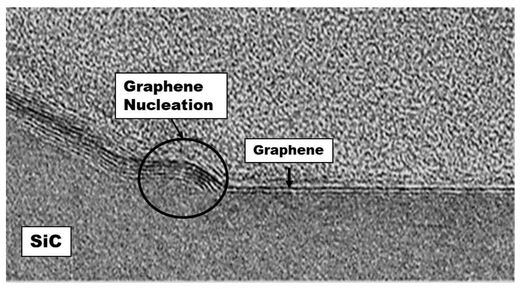
INTRODUCTION

High performance graphene electronic devices require high quality graphene obtained either by CVD on Cu foils or epitaxial graphene (EG) on SiC[1]. In this work, we report some preliminary results on the development of electrical devices based on large anisotropic single crystal EG flakes obtained on the C-face of SiC by high temperature sublimation[2]. The EG flakes were transferred to SiO_2 substrate via PMMA-assisted electrochemical delamination technique[3] and electrical contacts were aligned and patterned by e-beam lithography and lift-off process. Both structural and electronic characterization indicate that high crystalline quality of EG is basically preserved upon electrochemical transfer as well as device fabrication.

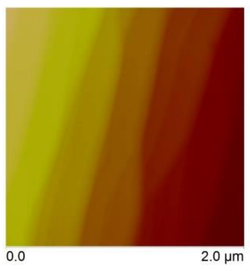
EPITAXIAL GRAPHENE DEPOSITION

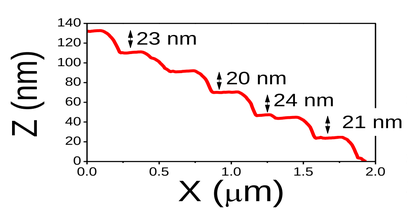


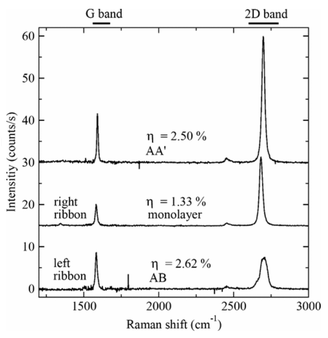
Epitaxial Graphene isolated flakes grown on the C-face of SiC.



Exemplary HRTEM cross section micrograph of EG growth on Si-face SiC by high temperature sublimation.

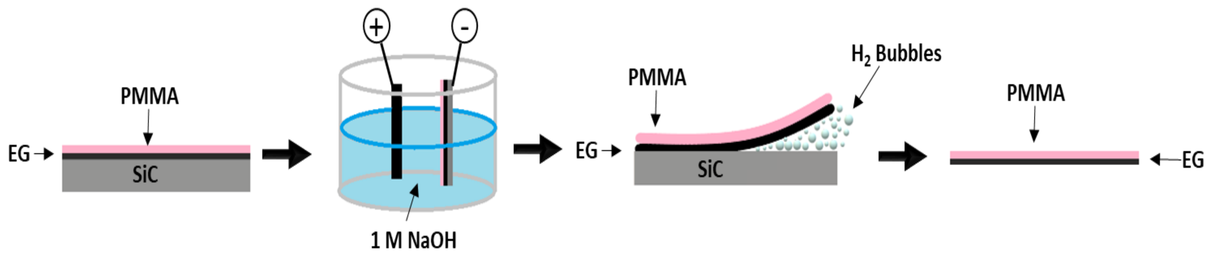




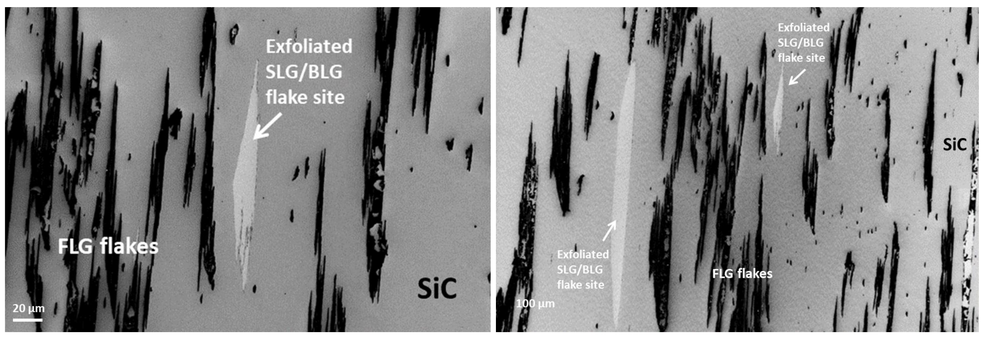


SLG to FLG islands nucleating and growing on the step bunched SiC surface. Raman spectra acquired in the middle of C-face SiC graphene ribbons [2].

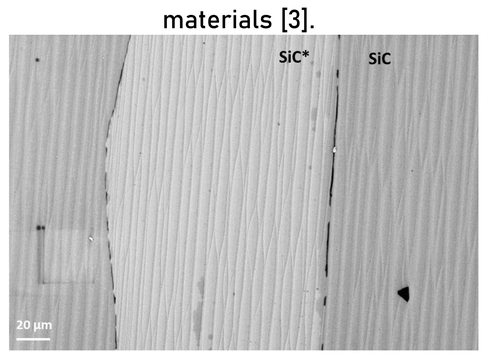
SELECTIVE EXFOLIATION OF SLG/BLG BY ELECTROCHEMICAL DELAMINATION



The delamination can be realized upon water electrolysis.
Flakes traction is based on the creation of H2 bubbles at the graphene-SiC interface, thus breaking the van der Waals or covalent bonds between both materials [3].

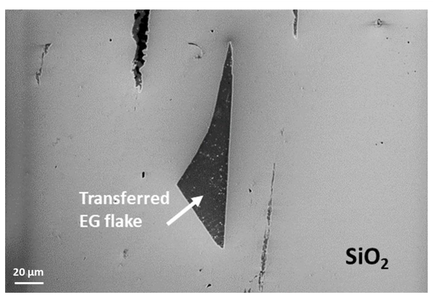


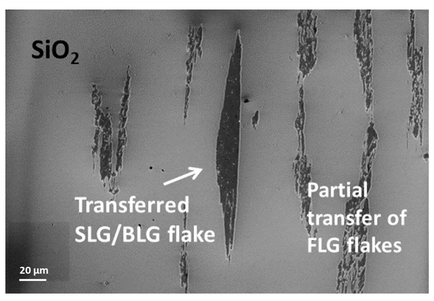
Electrochemical exfoliation of isolated flakes of epitaxial graphene on SiC substrates.



SLG/BLG flakes were preferably delaminated instead of graphitized islands.

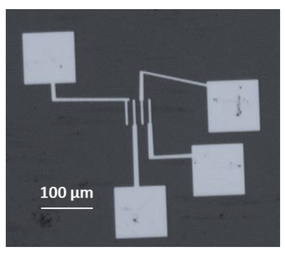
EPITAXIAL GRAPHENE FLAKE TRANSFER



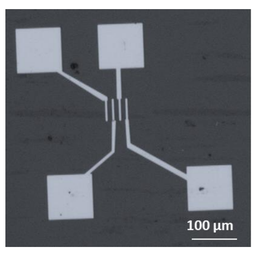


SEM images displaying the results of transfer. Integral SLG/BLG flakes are transferred on SiO_2 substrate. Partial FLG flakes can be transferred too, but typically they present structural damage or tend to be broken.

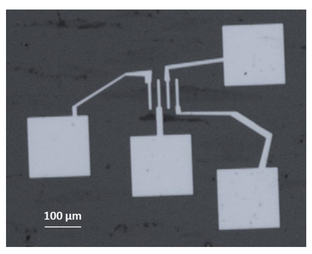
EPITAXIAL GRAPHENE FABRICATION of ELECTRONIC DEVICES



Device 1



Device 2



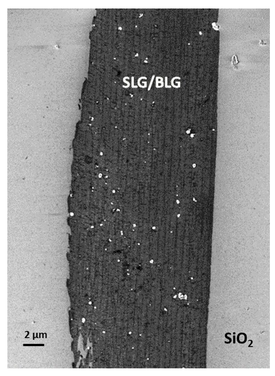
Device 3

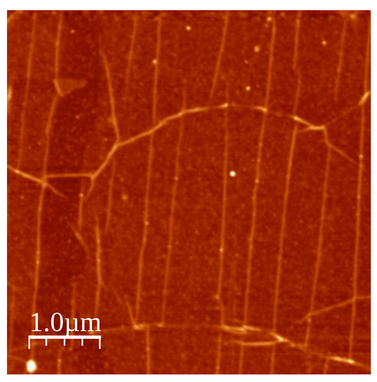
Specific SLG flakes were identified, localized and electrically-interfaced with dedicated metal contact designs.
Three electronic devices were realized and electrically characterized.
The electrical contacts were aligned and patterned simply by using e-beam lithography, thin film evaporation and resist lift off process.

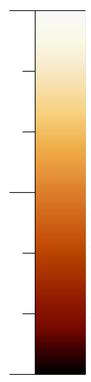
FUTURE WORK

The results presented in this poster are a preliminary study for the realization and application of epitaxial graphene in electronic devices.
Further electrical tests will be performed for the precise evaluation of the electronic properties and potential electrical characteristics of the devices.
Back gated devices will be used in order to determine carrier' mobilities. Finally, Reconfigurable devices based on epitaxial graphene could be achieved adding top-gate structure.

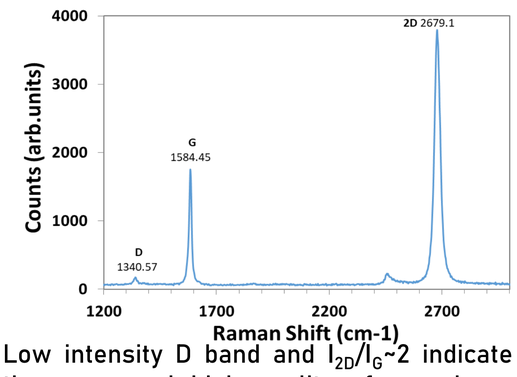
MORPHOLOGICAL and STRUCTURAL CHARACTERIZATION OF TRANSFERRED FLAKES





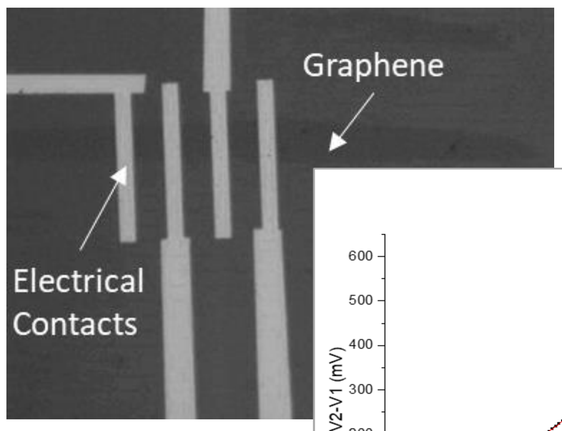


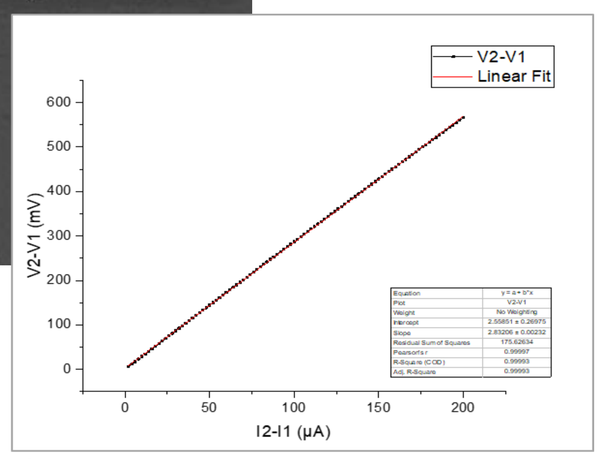
Electrochemical Exfoliation provides graphene flakes with well defined and clean-cut edges.
Transferred EG flakes reproduce the characteristic terrace topography pattern of the SiC substrate upon high temperature process, even after being transferred to SiO_2 as can be seen in AFM image.



Low intensity D band and I_{2D}/I_G~2 indicate the preserved high quality of monolayer epitaxial graphene, confirming the preservation of crystal quality upon delamination from SiC and transfer.

RESULTS of PRELIMINARY ELECTRICAL CHARACTERIZATION





- Electrical characteristics are based on 4-probe technique.
- The linear I-V relationship confirms the obtaining of ohmic contacts.

Device	R_{Sheet} (kΩ)		$R_{Contact}$ (kΩ)	
	Positive I/V branch	Negative I/V branch	Positive I/V branch	Negative I/V branch
1	0.45	0.46	1.93	1.72
2	0.45	0.45	1.18	1.19
3	0.38	0.39	1.71	2.34

Obtained values are aligned with results reported in the literature for epitaxial graphene [4].
Our devices could be easily further improved by applying suitable treatments prior to metal deposition, such as plasma treatments [5] of the contact areas or post deposition treatments such as rapid thermal annealing [6].

ACKNOWLEDGMENTS

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